It improves the surfaces of parts by increasing fatigue life and reducing stress corrosion cracking. Here is how it fits in with other finishing methods...

Part I

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Coatings are normally applied on metal surfaces to lengthen service life. They protect from corrosion, for example, or increase abrasion resistance.

Unfortunately the application of coatings may shorten service life of certain types of parts. Electroplates, for example, can induce tensile stresses that adversely affect fatigue life.

Some electroplates have tiny cracks, invisible to the naked eye, which may propagate into the basis metal.

Coatings applied by flame spray, electroless plating and other methods of covering one metal with another may also cause failure of parts later subjected to stresses.

The same is true of metal-removal operations such as grinding and electrochemical machining and deburring: they disturb the surface in ways which may be detrimental.

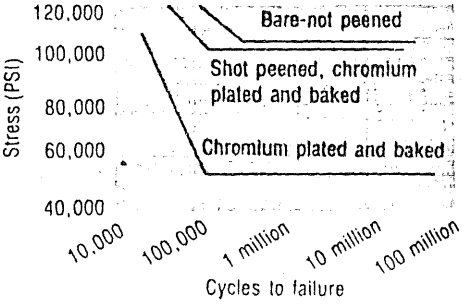
Fatigue life, then, is often adversely affected by stresses induced by many of these coating and finishing operations.

Fatigue life of metal parts becomes more important as the number of lighter-weight and faster-moving parts increases in industry.

There are a number of methods for improving fatigue life, including rolling, induction hardening, flame hardening, carburizing, nitriding and shot peening. All induce compressive stresses.

Shot peening is one of the most versatile and effective of these processes. It induces compressive stresses on external as well as internal surfaces. There is no limitation as to the hardness of the surface on which it can be used.

Shot peening consists of bombarding the surfaces of metal parts with round steel shot or glass beads under carefully controlled conditions. The peening causes the material to yield on the surface and



1. CYCLES to failure of 4340 steel, 52 to 53 Rc, rotating beam fatigue test. "Bare" represents fatigue strength of polished steel; "chromium plated and baked" shows effect of plating; "shot peened, chromium plated and baked" shows effect of shot peening prior to plating.[1]

thus places a layer of the surface in a uniform compression.

A fatigue crack will not originate in or propagate into a surface that is adequately stressed in compression. Since nearly all fatigue cracks start at the surface, and usually at a stress-concentrated area such as a scratch, sharp corners, machining marks, fillets, keyways and other changes of sections, the compressive stress induced by peening greatly enhances fatigue life.

The magnitude of the compressive stress has a direct relationship to the yield strength of the material. The depth of the compressive stress depends upon the kinetic energy of the ball hitting the surface: the larger the ball and the greater the kinetic energy, the deeper the compressive stress. For a given amount of kinetic energy, the larger the ball, the better the surface finish.

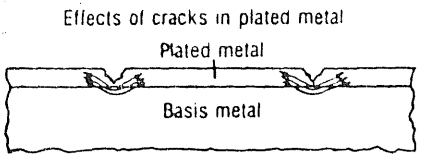
The depth of compression that should be applied to a particular component depends upon the application. If a part is subjected to considerable abrasion and wear in the field, for example, deeper compression would be more successful from a fatigue life performance standpoint.

Peening flame-sprayed coatings. The application of flame-deposited metallic coatings is becoming more widespread, not only to restore dimensions of worn parts, but to protect new parts against corrosion and abrasion. Unfortunately such coatings can reduce fatigue strength by up to 60 pct.

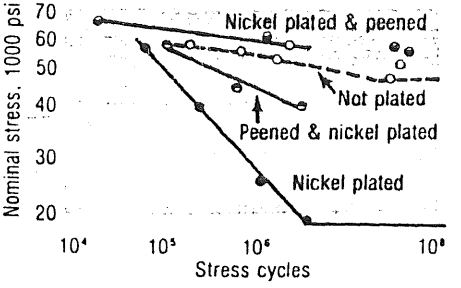
Peening before electroplating. The application of electrodeposits also may reduce endurance of the basis metal (Fig. 1). Several factors are involved:

1. Tensile stresses induced in the basis metal by electrodeposition of certain metals.

2. Electroplates often have minute cracks. These will propagate



2. CRACKS in plated metal may propagate if part is subjected to cyclic loading.[2]



3. STRESS CYCLES, rotating beam test, showing uncoated, nickel plated and peened specimens.[3]

into the basis metal when a part is subjected to cyclic loads. (Fig. 2).

3. The hard and brittle plated surface is extremely notch sensitive and susceptible to fatigue cracks.

4. The hazards of hydrogen embrittlement are always present.

Federal Chrome Plating Specification QQC-320 calls for parts that are designed for unlimited life under dynamic loads to be shot peened and baked at 375F for not less than three hours. This applies particularly to steel parts having a hardness above Rockwell C40.

EN on 4340. On 4340 steels (180,000 psi tensile strength) electroless nickel (EN) plated (.001 inch thickness of plate), the fatigue life on flat bending specimens to 90,000 psi is as follows:

Polished ..... 54,000 cycles
Shot Peened ..... 200,000 cycles
EN Plated ..... 39,000 cycles
Shot Peened and EN Plated
..... 141,000 cycles

Fig. 3 shows typical stress-number cycles (SN curves). The advantages of shot peening prior to nickel electroplating are evident as is the value of nickel plating and then shot peening, which gave the highest fatigue life.

It should be kept in mind that the electroplating did not alter the static strength of the steel.

Silver plating. Some critical components such as those in aircraft engines are silver plated. They must be checked to be sure that the deposit has adhered properly. Shot peening has often been used to determine that adhesion is adequate. This is accomplished by shot peening the silver plate (allowing for final machining of plating after shot peening tests). If the plate blisters or peels, it is an indication of a poor bond between the plating and the basis metal.[4]

ECM, EDM. Shot peening has been effectively used after electrochemical machining (ECM). Although ECM should not include significant stresses, a reduction in endurance strength is caused by surface softening (Rebinder effect). Random surface imperfections are also contributors to this reduction.

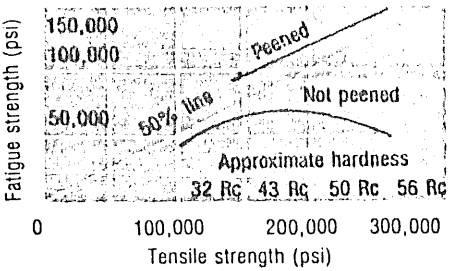
4. ROTATING bending fatigue limit of steel (right) at various hardness levels.[5]

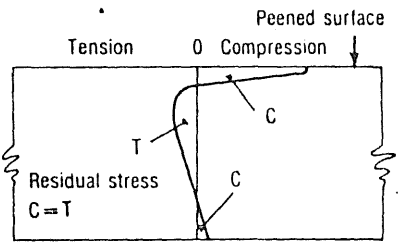
Shot peening is a good post-treatment to restore the endurance limit.

Although electrical discharge machining is essentially force free, eroded components are not necessarily stress free. Not all the molten metal produced during the discharge is expelled into the working gap. That which remains resolidifies to form a hard skin on the work surface. The accompanying thermal stresses, plastic deformation and shrinkage induce residual tensile stress in the workpiece. Under certain conditions this approaches the ultimate tensile strength of the material near the surface. Shot peening restores the fatigue life of parts that have been electrodischarge machined.

When steels are operating at a tensile strength above 180,000 psi (40 Rockwell C), the fatigue strength begins to fall because of brittleness and notch sensitivity at the surface. By putting the surface of the metal in compression, one can increase the fatigue strength of a part to almost three times that of a non-shot peened specimen at a strength level of approximately 280,000 psi (53 Rockwell C). (Fig. 4).

Grinding and peening. Another detrimental operation is grinding. Under normal conditions it will induce residual tensile stresses in the ground surface. These stresses can be high enough to start a fatigue crack. This is especially true when



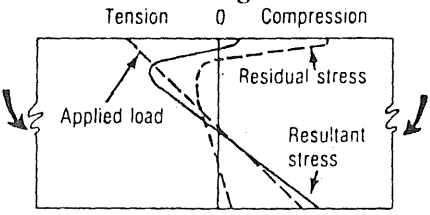


5. DISTRIBUTION of stress in a shot peened beam with no external load.

there is a combination of high residual tensile stresses produced by grinding plus an applied tensile load.

It is for this reason that shot peening is frequently used as "insurance."

Fig. 5 shows qualitatively the distribution of stress in a beam that has been shot peened on the upper surface with no external load applied. Since the beam is an equilibrium, with no external forces, the area under the stress distribution curve in the region of compressive stress must be equal to the corresponding area under the curve in the region of tensile stress. Further, the sum of the moments of these areas must be equal to zero.



6. DISTRIBUTION of stress in a shot peened beam with external load applied. Solid line is the resultant stress.

Fig. 6 illustrates the same beam as shown in Fig 5 but with an external bending moment applied after shot peening. The resultant stress at any depth will be equal to the algebraic sum of the residual stress and the stress due to the applied load at that depth. The resultant curve of the stress distribution is shown as a solid line and the individual components are shown as dotted lines. Note that even after loading, the peened surface still retains a compressive stress. This can be depended upon to prevent formation of surface cracks.

Preventing seal leakage. Shot peening works quite successfully in areas where one experiences leakage of seals. Glass-bead peening eliminates the directional marks left by the grinding and the slightly roughened but evenly peened surface is superior to a lapped and ground surface.[6] **PF**

Editorial Note: References will be published at the end of Part II, next month.

(To be continued in March PF)